CO2 Laser Status

Author: I Pogorelsky

Progress

The newly established single-pulse regime of the CO2 laser operation (with isotopes) is routinely used now in users experiments where the laser beam interacts with matter (ion acceleration) or electron beam (Compton scattering). A single laser pulse provides a better defined source for producing Compton x-rays and adds to their intensity. Recent experiments conducted by a collaboration including INFN (Italy) and UCLA progressed in characterizing the Compton x-ray source for ultra-fast medical imaging. Ion acceleration runs conducted with our collaborators from Imperial College (UK), LULI (France) and SBU gave further insight into the physics of laser-plasma interactions at over-critical densities and provided new information to plan for further improvement in the Radiation Pressure Acceleration process. Recently improved optical diagnostic setup (see Fig.1) allows capturing the sequence of interferograms in a single laser shot.

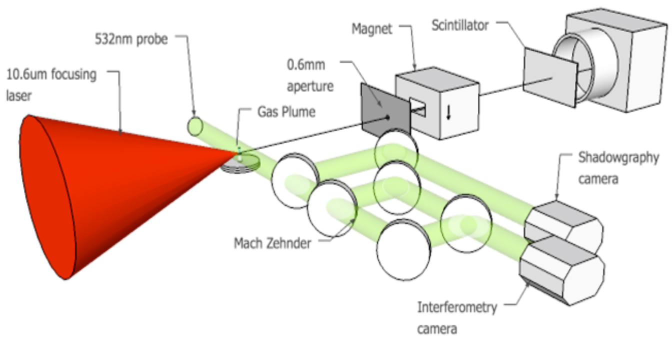


Fig 1: Ion acceleration experiment with optical diagnostic

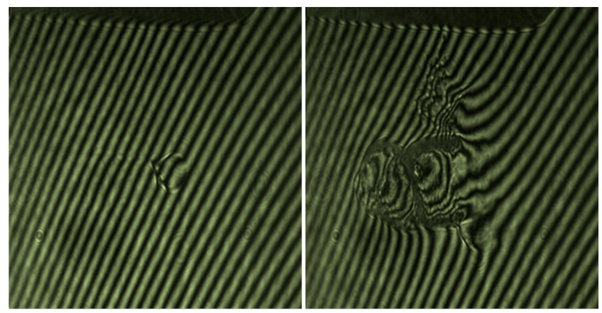
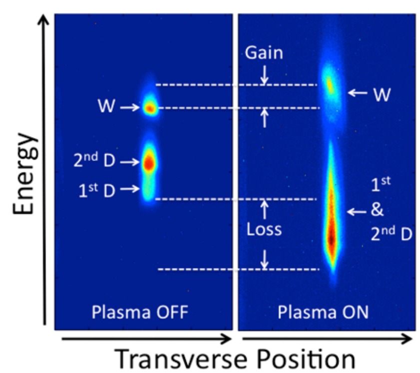


Fig 2: Series of interferograms illustrate the laser plasma dynamics over the 0.5 ns interval

Plasma Wakefield Acceleration

Author: P. Muggli

The ATF beam is ideal to study the physics of the plasma wakefield accelerator (PWFA). One of the key parameters of the PWFA is the transformer ratio R, the ratio of the peak accelerating field behind a drive bunch (DB) or train of drive bunches (TDBs) and the peak decelerating field inside the DB (or TDBs). In the linear theory of the PWFA the energy transfer efficiency between the DB (or TDBs) and the wakefields is directly proportional to R. We have demonstrated a masking method to tailor a TDBs followed by a witness bunch out of a single electron bunch. We use this train to demonstrate the resonant excitation of wakefields by an equidistant TDBs (~300μm spacing). We vary the capillary discharge plasma density between ~1014 and ~1018cm-3, thereby changing the frequency or wavelength of the accelerator. The resonance is reached when the relativistic wakefield wavelength is equal to the TDBs spacing. We will also use this method to generate large R wakefields in the linear regime of the PWFA. We will use permanent magnet quadrupoles (PMQs) for strong focusing to access the nonlinear regime of the PWFA and investigate the nontrivial issue of large R nonlinear wakefields, issue relevant to a future PWFA-based collider. One interesting difficulty in these experiments is the generation of coherent synchrotron radiation (CSR) by the TDBs with sharp edges. The CSR significantly modifies the energy spectrum of the TDBs.



Left: *energy of the train of two drive bunches followed by a witness bunch with the plasma off. The effect of CSR is to redistribute the charge in the spectrum, but not in time.*
Right: *energy of the train at low plasma density (non-resonant, ~1015cm-3), the two drive bunches lost energy, while the witness bunch gained energy. In this case R<1.*

Flat Crystal Spectrometer

Contributions by G. Andonian, S. Barber, F. O'Shea, O. Williams and J. Rosenzweig

The inverse Compton scattering (ICS) effect promises to be an excellent source of high-energy gamma rays of narrow spectral width and known polarization. The ICS experiment at the BNL ATF aims to develop a complete characterization of the photon production during the process. Using the ATF parameters (beam energy of 85 MeV, CO2 laser power > TW), the ICS process is predicted to create copious X-ray pulses of ps duration reaching photon energies up to 14 keV. The goal of the flat crystal spectrometer experiment at the ATF is to diagnose the unique spectral-angular correlation that is the signature of the ICS interaction. A single crystal silicon wafer is put into the path of the X-ray beam to reflect only those photons that meet the Bragg criterion. As the crystal is rotated, different parts of the photon beam are reflected and several shots can be used to reconstruct the X-ray spectral-angular distribution. The narrow bandwidth of the reflection process signifies that all broadening in the reflected signal is due to the bandwidth of the laser-electron interaction. The principle difficulties of the experiment are the careful alignment of the detector for the reflected X-rays and improvement of the signal-to-noise ratio (SNR) of the detector for X-rays of 8-12 keV. Recent experimental runs at the ATF have produced promising results. The X-ray energy is calibrated by inserting a Ni-foil (K-edge 8.3keV) and fitting the intensity peaks of the distribution after strong K-edge filtering. The recent runs demonstrated a 9.3 keV photon energy; the 1st order Bragg diffraction angle is 12.2 deg for this case. The crystal and detector were arranged along this angle (on a rotation stage for precision alignment to the Bragg angle) and the corresponding spectra were collected (Figure 1). A hard edge is clearly seen in the image. This hard edge is predicted both from analytical studies and simulations, however experimental limitations in aperture may also produce such a pattern. Further upgrades in alignment, optics, and X-ray collection will improve the system SNR to unambiguously assert that the data confirms the simulation results.

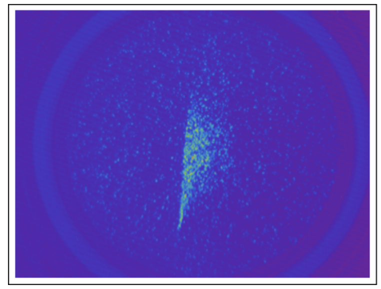


Figure 1: Spectral image at Bragg angle of 12.2 deg (average of 6 shots).

Current Filamentation Instability

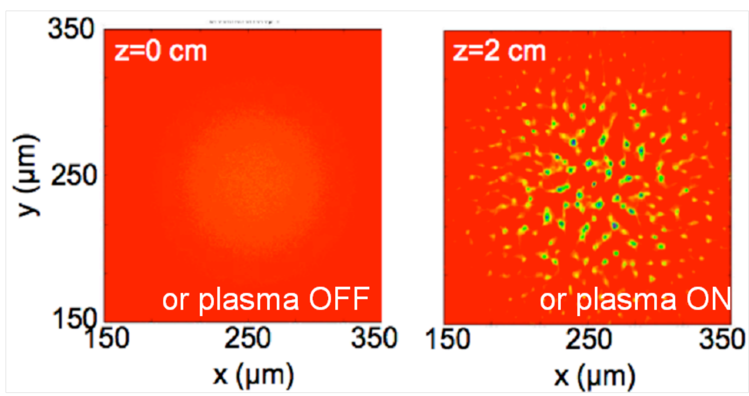
Author: B. Allen

Progress

The Current Filamentation Instability, CFI, is a basic beam/plasma instability with implications in astrophysics and the fast igniter fusion concept. It may occur in the parameter regime with a relativistic beam and where the transverse beam size is much larger than the plasma skin depth. In this case the plasma return current flows through the electron bunch and slight current imbalances generate magnetic fields that drive the instability. The experiment is being conducted on beamline one in the Compton chamber and leverages the experience and components from the PWFA experiment. To this point we have done the initial experimental setup and conducted a preliminary run to confirm the setup. The imaging system has been analyzed and is providing resolution <10mm, the filaments are expected to be ~10mm, and thus should be sufficient.

Challenges/Issues

When we ran with e-beam, radiation was generated which was brighter than the desired OTR of the Au/e-beam at the capillary exit. The speculation is that this additional radiation is OTR from the e-beam impinging on the front mirror of the microscope objective. This was verified by first rotating the objective so the e-beam directly hits the second mirror (rather than the first mirror) and seeing a significant reduction in the radiation. To reduce the radiation in the typical configuration a lead cone of ~1.5 radiation lengths was attached to the front of the microscope objective and showed a reduction, but not elimination, in the resulting radiation. The next step is to install a Tungsten cone of ~3 radiation lengths in place of the lead cone, with the anticipation that the radiation is further reduced.



*Simulation results of beam density along axis of the beam: (**left**) Gaussian beam density at entrance to uniform plasma or plasma off, similar to that at the plasma exit, (**right**) filamentation of beam after 2 cm of propagation in plasma. Both images have the same color map showing the filaments larger current and therefore stronger magnetic field than the incoming beam. Simulations conducted with Particle-in-Cell (PIC) code QuickPIC from the UCLA/IST collaboration*